A robot system for evaluating plaque removal efficiency of toothbrushes in vitro

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Abstract

A robot system simulating three-dimensional brushing motions as a function of time has been developed. In association with a typodont and either artificial plaque or chromogenic stain, the robot system can be used to assess the plaque removal efficiency or the cleaning effectiveness of toothbrushes. In particular, the influence of different brush head designs of powered toothbrushes was examined. The study compared the plaque removal efficiency of a cup-shaped brush head (Braun Oral-B EB 5) and a modified brush head (Braun Oral-B EB 9) that incorporates longer filaments on the outer ring, designed for additional interdental penetration. A specially designed artificial plaque was applied to the plastic teeth of typodonts. Artificial teeth were cleaned by the robot system for a 2-minute period with a wet brush head without a dentifrice. The remaining plaque was assessed visually by two independent examiners, with a modification of the global Plaque Index. In comparison to the EB 5, the new brush head significantly reduced artificial plaque overall. In vitro data demonstrated the ability of the robot system to reveal reproducible significant differences of the cleaning effectiveness of powered toothbrushes. (Quintessence Int 1997:28:441-445.)

Clinical relevance

The brushing robot is an effective tool for evaluating powered toothbrushes and could become an appropriate method for preclinical evaluations. Data demonstrated that the plaque removal capability of the newly designed EB 9 brush head was significantly higher than that of the EB 5.

Introduction

In recent years, powered toothbrushes have been developed in a number of ways to improve their efficacy with respect to the removal of plaque. Developments have included modifications in brush head design as well as changes in the speed and angle of motion of the brush head. To assess the success of these various developments, it is necessary to carry out both laboratory and clinical studies. However, most clinical studies are carried out only for a short-term period. Because of the novelty effect that occurs when subjects use new powered toothbrushes, it is difficult to assess the results of these studies objectively. Furthermore, because of a lack of volunteers representing average oral hygiene for long-term clinical studies, most often researchers have to rely on participants who are involved in dentistry and oral care, such as dental students or dental nurses. These groups mostly show optimal oral care and oral hygiene. Because of a strong correlation of oral hygiene to socioeconomic characteristics, they are not representative of the average patient.

Further problems appear with individual variations in jaw and tooth formation, different restorative treatments, and age. All of these factors result in differences in interproximal spaces and the amount and the character of the plaque. Laboratory studies of plaque and stain removal can be carried out rapidly but may not necessarily give an accurate representation of the clinical situation.
Until now, pilot clinical studies have remained a primary requirement for the evaluation of a change in plaque-removing potential. To enable a more rapid assessment of plaque removal, the objective of this study was to develop a robot system that simulates the average clinical use of a toothbrush. In addition, a specially designed new brush head with a number of longer outer filaments was to be compared to the conventional brush head, when used in an established oscillating/rotating driving system.

Method and materials

Robot system

A six-axis industrial robot (Asea Brown Boveri), originally developed for industrial spot welding, has been modified to simulate normal clinical use with a powered toothbrush (Fig 1). The brushing motion in space and time is computer controlled. In addition, the system allows the standardization of brushing forces in well-defined ranges.

Tooth model and artificial plaque

Artificial teeth of maxillary and mandibular typodonts (Frasaco, Tettnang) were sandblasted for 20 minutes with aluminum oxide powder of 50 μm diameter and covered with an artificial plaque solution in a standard procedure. The solution (Waco Fin, Heinrich Wagner) was applied with a paintbrush in a standardized manner over a 2-minute time period (Fig 2). In several pretrials, the adherence of the artificial plaque was found to be similar to the adherence of true intraoral plaque to natural teeth. The color blue was chosen for the artificial plaque to provide optimal contrast between the artificial teeth and the artificial gingiva. Following a 6-minute drying period for the artificial plaque, the typodonts were mounted on the robot system.

Cleaning procedure

The teeth were cleaned by the robot for 2 minutes (1 minute maxillary and 1 minute mandibular typodont) using a standardized wet brush head without a dentifrice (Fig 3). The omission of a dentifrice was to avoid any removal activity related to the dentifrice. This method has been previously assessed for standardization and reproducibility. In this test, the pressure applied by the robot system was adjusted to 1.8 ± 0.2.

Testing procedure

Two different brush heads (EB 5 and EB 9), designed for the Braun Oral-B Plaque Remover (D7, oscillating angle 70 degrees, frequency 47 Hz), were tested in a crossover study design for a total of six tests per brush head. A new brush head was used for each test. The EB 5 brush head is a commercially available brush head of the D7 with a diameter of 13 mm. The bristles are arranged in a cup-shaped configuration with a longer (length: 7.8 ± 0.1 mm) circular ring of outer bristles 0.15 mm in diameter and two inner rings of shorter (length: 7.1 ± 0.1 mm) bristles 0.13 mm in diameter. The EB 9 is the commercially available brush head of the Braun Oral-B Ultra Plaque Remover D9.
The brush head shows a different filament design with three tufts of longer bristles (length: 8.2 ± 0.1 mm) in the outer ring designed to improve interdental cleaning and for better penetration of the fissures on the occlusal surfaces. The shorter bristles are 7.5 mm in length. Bristle diameters of longer and shorter bristles are 0.15 mm (Fig 4).

Following the 2-minute brushing cycle, the typodonts were examined for remaining plaque by two independent examiners, blinded to the brush head used. This visual index was a modification of the global Plaque Index, in which buccal, lingual, and occlusal surfaces are assessed. The error of studies examining interexaminer and intraexaminer reproducibility have shown to be less than 2% (unpublished data on file, Braun).

Statistical analysis

Statistical analysis was carried out at the 1% level with a two-sided double t-test. The Kolmogorov test was used for examination of normal distribution. In addition an F test has been applied to check the condition of similar standard deviations. If the F test showed significant differences in the standard deviation, the modified t-test (Welch test) was applied.

Results

Both tested brush heads were successful in cleaning the artificial tooth surfaces. The newly designed EB 9 brush head combined with the D 7 system showed a statistically significant ($P < .01$) improvement in plaque removal compared to the EB 5/D7 brush head system on all surfaces. The plaque removal values for the EB 9 and EB 5 brushes were 85.8% ± 5.6% and 68.1% ± 6.2%, respectively, measured in comparison with the total tooth surfaces. The complete plaque scores are shown in Table 1 and Fig 5.

Discussion

To collect representative data about the efficacy of powered toothbrushes within a short time period, more...
Ernst et al

and more in vitro tests have been conducted. Most examinations concerning toothbrushes and other oral care devices have been carried out in vivo studies, because of a lack of possibility of in vivo simulation in laboratory studies. For volunteers, getting used to a toothbrush under regular conditions is very difficult in clinical studies and is only possible over a long time period.

The use of a computer-controlled robot system opens the door to a wide variety of laboratory tests under clinical conditions. One of the main advantages of an in vitro robot system is the reproducibility of a once-programmed process. Because of a specially developed teaching program, the robot used in this study is able to perform similar movements applying well-defined pressures in the same time period. Cleaning time has a strong influence on the cleaning efficacy of toothbrushes. Van der Weijden et al found the main cleaning effect of powered toothbrushes was within the first 2 minutes. Therefore, and in accordance with previous studies, a 2-minute brushing period was considered to be optimal for the test. Brushing pressure also has a strong influence on cleaning results. In accordance with other in vitro experiments, the applied pressure used in this test was 1.8 ± 0.2.

The proof of statistical significance in a small sample and the small standard deviations show the ability of this robot system to assess the plaque removal capability of different brush heads even within the same driving system.

The statistically significantly better removal of plaque by the EB 9 compared to the EB 5 brush head used on the same driving system indicated that the longer filaments of the outer ring enabled improved penetration in the fissures on the occlusal surfaces and in the interproximal areas.

References

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